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HUNGER IN THE INFANT

Thesis Submitted to the Faculty of the Graduate School
of the University of Minnesota

BY
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HUNGER IN THE INFANT*

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Cannon and Washburn,[1] and Carlson and his colaborers have given us a proved method for studying hunger objectively; its time of occurrence, its intensity, its effects, and the means by which it may be produced or inhibited. They have shown that contractions of the so-called empty stomach cause the hunger sensation. These contractions depend in part on vagus tonus. They can be increased by chemical changes in the blood, but are primarily due to a gastric mechanism as purely automatic as is that of the heart.

Impulses set up by these contractions and carried to the higher centers are, in the normal consciousness, recognized as hunger. These impulses produce secondary effects such as restlessness and irritability. They increase the reflex excitability of the central nervous system, the heart beats faster, and there are changes in the vasomotor mechanism. Well fed, sedentary adults seldom experience hunger. The prime factor in their desire for food depends not on the basis of distress due to the contractions of a hollow viscus, but on "the memory processes of past experience with palatable foods." This psychic factor is appetite, and its absolute distinction from the physical factor, hunger, must be kept in mind.

Working on dogs, Patterson, in 1914, showed the gastric hunger contractions to be much more frequent and vigorous in young than in older animals. In 1915, Carlson and Ginsburg described the great intensity of hunger contractions in the human new-born. Previous to that year no productive analytic studies of the hunger sense in the human infant had been made. Appetite and hunger were not distinguished, and the sucking mechanism alone had been analyzed.

In 1888, Auerbach distinguished the infantile type of sucking from the voluntary inspiratory type employed by the adult, and in 1894 Basch, disproving the older theory of Preyer that sucking is instinctive, showed it to be entirely reflex.

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1. All references to the literature will be found at the end of the article.

Czerny, in 1893, observed that an infant awakened a short time after taking his fill from the maternal breast, would again suck vigorously if placed on it, and concluded that sucking per se could not be considered as a sign of hunger. A few years later (1900) Keller wrote that, since the normal infant sleeps three hours after nursing, although its stomach is empty in two hours, the emptying of the stomach cannot be considered a positive criterion of need for food. Pies, in 1910, considered the reddening and eczema of the lower lip which occurs in undernourished infants as a sign of hunger, and referred it directly to the infant's fruitless sucking. In 1913 Schlossmann concluded from extensive observations on semistarved infants that the sensation of hunger exists only in the imagination.

Meyer and Rosenstern studied the results of starvation in the different types of alimentary disorder, recording particularly the pulse, temperature, respiration and weight changes. Rosenstern later (1911-1912) wrote extensively on the general subjects of hunger and inanition in infancy. These studies are all defective in that they do not distinguish the various factors concerned. Neumann, Pfaundler, Cramer, Süszwein, Barth, and Kasahara have discussed the subject of disturbances in the food urge largely from the point of view of imperfections in the sucking mechanism.

The present studies are concerned particularly with the gastric factors in the urge for food. The major of these, the hunger contractions, was studied by means of apparatus similar to that used by Carlson. A rubber balloon of about 20 c.c. capacity attached to one end of a small soft rubber catheter is inserted into the stomach and inflated, the catheter is attached to a bromoform manometer with a cork float and a writing pennant which records the gastric movements on smoked paper.

The material investigated included 5 premature infants weighing from 1,200 to 2,500 gm., 40 full term new-borns under 3 weeks of age, and 11 older babies, 5 between 1 and 2 months, 2 between 3 and 4 months, 3 between 4 and 6 months, and 1 boy of 2 years with a surgically induced gastric fistula made necessary by the effects of corrosive in the esophagus. The gastric movements of some of the infants were recorded only once; on others as many as twenty observations were made.

Carlson and Ginsburg refer to the readiness with which most infants accept and retain the tube and balloon. It is naturally impossible to secure a graphic record of the stomach movements of a raging infant. Carlson and Ginsburg did their work on full term new-borns. These infants, as a rule, sleep quietly when not disturbed. The present work was carried on in a dimly lighted, quiet room. I had less difficulty when the infant was left undisturbed in his crib than when I

attempted innovations, such as threading a pacifier on the tube or having the infant held in the nurse's arms.

The older babies resent the presence of the tube, and with them it was often necessary to make repeated attempts to secure tracings. Some infants finally became accustomed to the presence of the tube and slept quietly, particularly if the experiments were conducted in the evening. Most of the tracings on the 2-year-old boy with the gastric fistula were made when he was awake. The greatest problem was to keep him sufficiently interested to prevent crying and restlessness and at the same time to prevent riotous hilarity. In his case the balloon was introduced directly through the fistula.

It is said that passage of the stomach tube in infants is apt to cause aspiration pneumonia. No ill results followed the procedure carried out in these studies.

Does the presence of the balloon in the stomach act mechanically to produce gastric contractions? Carlson states definitely that it does not, and gives the following reasons for his belief:

1. The presence of the distended balloon in the stomach between the contraction periods does not induce these contractions.

2. In Mr. V. [his gastric fistula case] the gastric contractions can be observed directly through the large fistula without any balloon in the stomach.

3. The contraction periods come on just as frequently without any balloon in the stomach and produce the same effect (hunger).

4. In pigeons the periodic strong contractions of the empty crop can be seen directly through the skin, and a balloon in the crop does not alter their frequency or intensity.

The results of this work fully confirm Carlson and Ginsburg's report that the stomach of the new-born infant exhibits greater hunger contraction than does that of the adult. The intervals between the contraction periods are often less than five minutes and usually not longer than from ten to twenty minutes. The first contraction period after a nursing is apt to consist of from five to twenty separate contractions and to last from two to eight minutes. The succeeding contraction periods frequently endure from thirty minutes to an hour or even longer. The duration of each contraction is about twenty seconds. In many of the infants the contraction time of the more powerful contractions, especially in those periods ending in partial tetanus, was about eighteen seconds. Except in the first contraction period after a nursing, endings in partial tetanus were frequently observed. Partial tetanus is sometimes present before the close of the period. With the apparatus used, the force of the single contractions usually sufficed to raise the column of bromoform 2 to 3 cm. During partial tetanus the bromoform may be raised 5 cm.

Patterson found practically continuous hunger contractions in premature pups. It is particularly easy to obtain graphic records of the

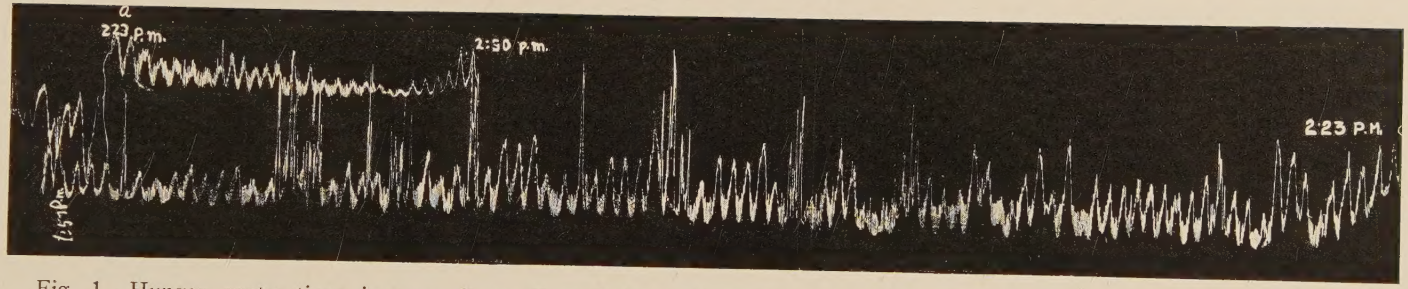

Fig. 1.—Hunger contractions in normal, new-born infant. Beginning of partial tetanus at extreme right in lower tracing.

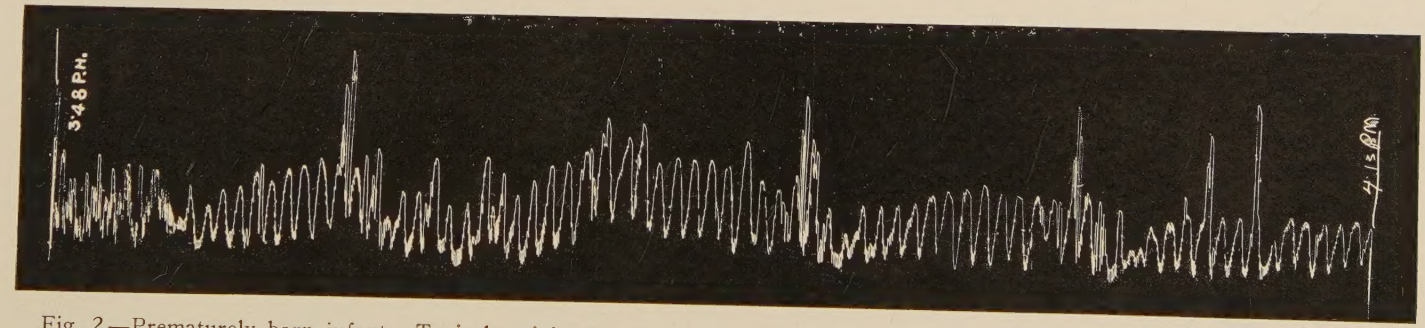

Fig. 2.—Prematurely born infant. Typical activity of the premature baby's stomach. Boy F., aged 15 days; weight, 1,536 gm.; getting 45 c.c. breast milk six times a day. Previous feeding at 2:30 p. m.

hunger contractions of the somnolent, prematurely born infant. The stomach of such an infant is in a state of nearly continuous contraction. The individual contractions require about the same length of time for their completion and are as powerful as those of the full term infant. In a tracing begun forty minutes after a feeding of 15 gm. of breast milk to a premature baby (Baby 5) weighing 1,510 gm., the record appears very like that obtained by Rogers from the crop of a pigeon in the second day of starvation. The periods of contraction last two or three minutes, with intervening periods of quiescence of about the same length. The individual contractions last twelve to fifteen seconds and raise the bromoform column 3 to 4 cm. Partial tetanus is frequent. Nine days later, when the infant was receiving more food, in spite of the fact that he had not gained in weight and that the tracing was begun five hours after his last feeding, the record obtained was similar to those from other infants.

Are the hunger contractions more frequent or more powerful in cyanosed infants? May they furnish a stimulus for crying with consequent better aeration of the lungs? In two such cases no significant increase or decrease in the hunger contractions could be observed. No records were taken from any cyanosed premature infants, although such infants are frequently slightly blue for the first few days.

Carlson, working on the adult, was unable to produce hunger contractions by any sort of stimulus acting directly in the mouth or in the stomach, except that he occasionally could, by suddenly distending the stomach, produce a few transitory contractions. He found, uniformly, that the only effect of such local stimulation was inhibitory. In general, the taste of salt, sour, bitter, or sweet; or the chewing of agreeable, disagreeable, or indifferent substances, all produce temporary inhibition of the gastric contractions. Chewing palatable foods by the adult when hungry causes an inhibition, made more lasting by the flow of appetite juice in the stomach.

Carlson found that acid and alkaline solutions, food and liquids in the stomach, all inhibit the hunger contractions. Inhibition from the stomach is less transitory than that from the mouth. Boldyreff showed that the periodic contractions of the empty stomach were inhibited by the presence of acid in the intestine. Brunemeier and Carlson completed and enlarged this work. They demonstrated inhibition from the presence of gastric juice or acid chyme in the small intestine. This inhibition from the stomach and intestine is reflex, partly through Auerbach's plexus, but mainly through the long reflex arc with the efferent path to the stomach muscles through the splanchnics.

Inhibition from the mouth is not present in the frog (Patterson). Carlson, who suspects that such inhibition involves conscious cerebral processes, has suggested experiments in infants to settle the point.

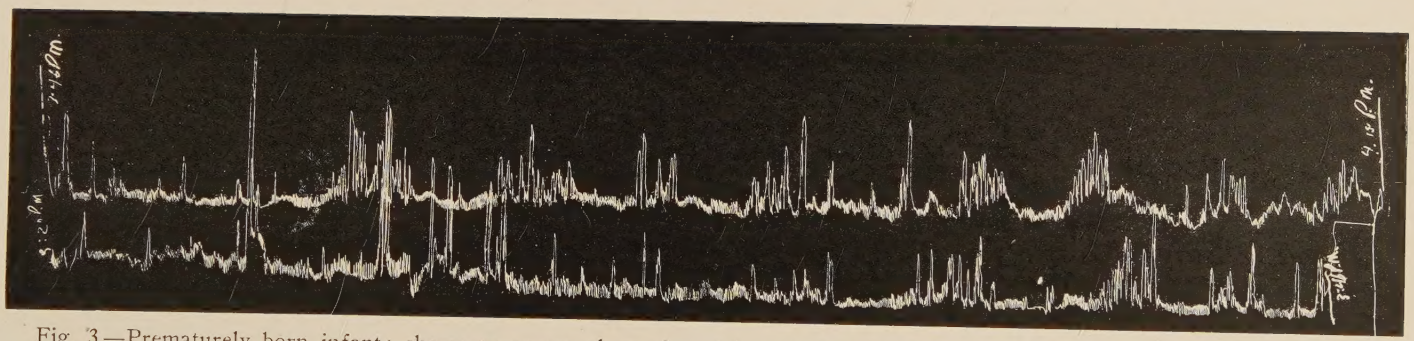

Fig. 3.—Prematurely born infant; shows numerous short, forceful contraction periods. Boy Von, 4 days old; weight, 1,510 gm.; birth weight, 1,715 gm.; at 2:30 p. m. received 15 c.c. breast milk.

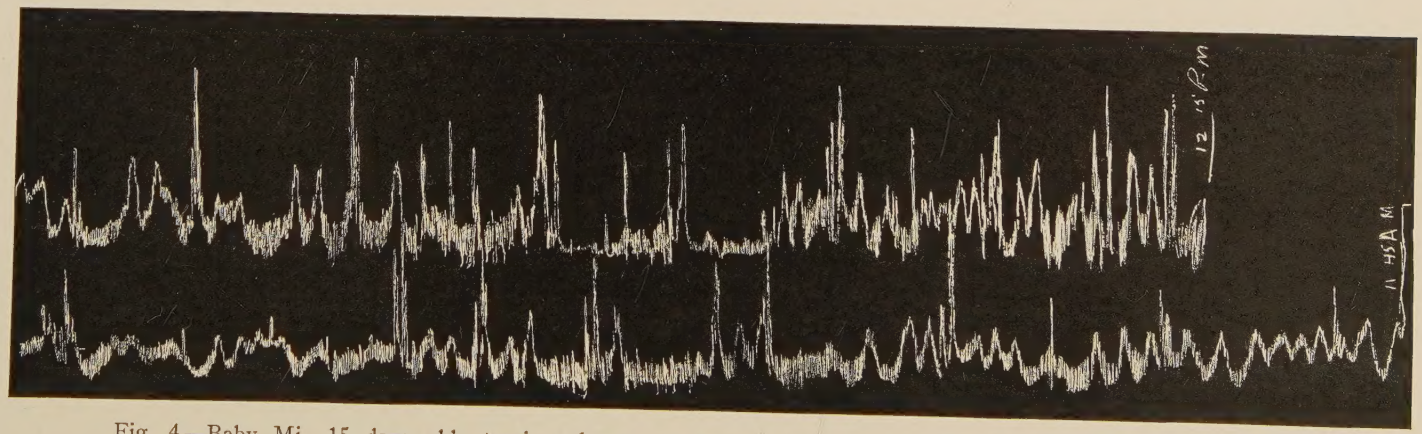

Fig. 4.—Baby Mi., 15 days old; tracing shows presence of hunger contractions in an infant who nursed poorly.

Repeated trials with breast milk, sugar water, common salt, quinin, and lemon juice in the mouths of premature and new-born infants in my study failed to produce inhibition of hunger contractions.

In general I obtained the same results in an infant of 8 weeks. A transitory inhibition occurred occasionally when sugar water was placed in his mouth. In none of the infants did chewing or sucking on the thumb or tube produce inhibition. Nor did such movements or the presence of sugar, breast milk or other substances in the mouth induce hunger contractions.

The boy of 2 years showed inhibition when sugar or protein milk (his diet at the time) was placed in his mouth. Quinin, dilute hydrochloric acid, small amounts of sugar water, table salt in crystals or solution, did not inhibit. Benzosulphinidum solution inhibited twice. It was not used subsequently. The sight of sugar did not inhibit. He began to cry when he saw his bottle if the latter were not given him immediately. Conseqeuntly the effect of his seeing the bottle on the hunger contractions could not be registered. During the periods of quiescence the sight of the nurse who fed him did not induce hunger contractions, although he began to whine and tease when she entered the room.

Apparently inhibition from the mouth was produced by those substances only which the child regarded as food. Quinin very evidently made a profound sensory impression, but did not inhibit the contractions. Dilute hydrochloric acid did not inhibit, while unsweetened protein milk (which is slightly sour) did.

Carlson's hypothesis as to the need of conscious cerebration for the production of inhibitory reflexes from the mouth would appear to offer the correct explanation. It seems to be agreed that the new-born infant leads a subcortical reflex existence (Soltmann-Cramer). Kussmaul and Thiemich note that the new-born infant accepts sugar and rejects salt, food that is sour and bitter — action which is almost certainly purely reflex on the part of the infant.

My work shows that when 20 c.c. of water or milk are introduced into the stomach during a contraction period inhibition follows invariably. This was found true in infants of all ages. With small amounts of water the inhibition often lasted only three or four minutes, when the contraction period would be resumed.

On the other hand, it was not unusual to recover from 15 to 40 cm. of clotted milk through the stomach tube even an hour after vigorous hunger contractions had begun. This is a considerable portion of the infant's meal, and in these cases would represent from one-sixth to one-fourth of his total intake at the previous feeding. Soltmann showed that the inhibiting nervous mechanism of the heart is much less effectual in the new-born infant than in later life. It seems possible

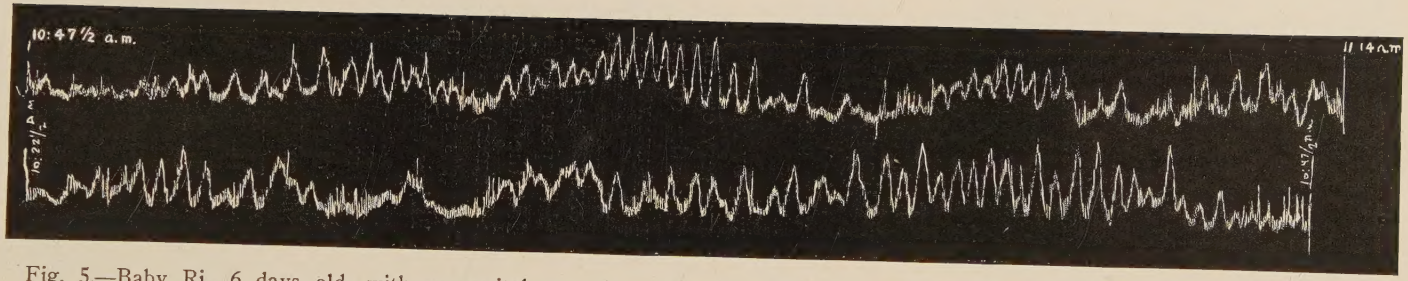

Fig. 5.—Baby Ri., 6 days old, with congenital myxedema; tracing showspresence of hunger contractions in a babe who nursed poorly.

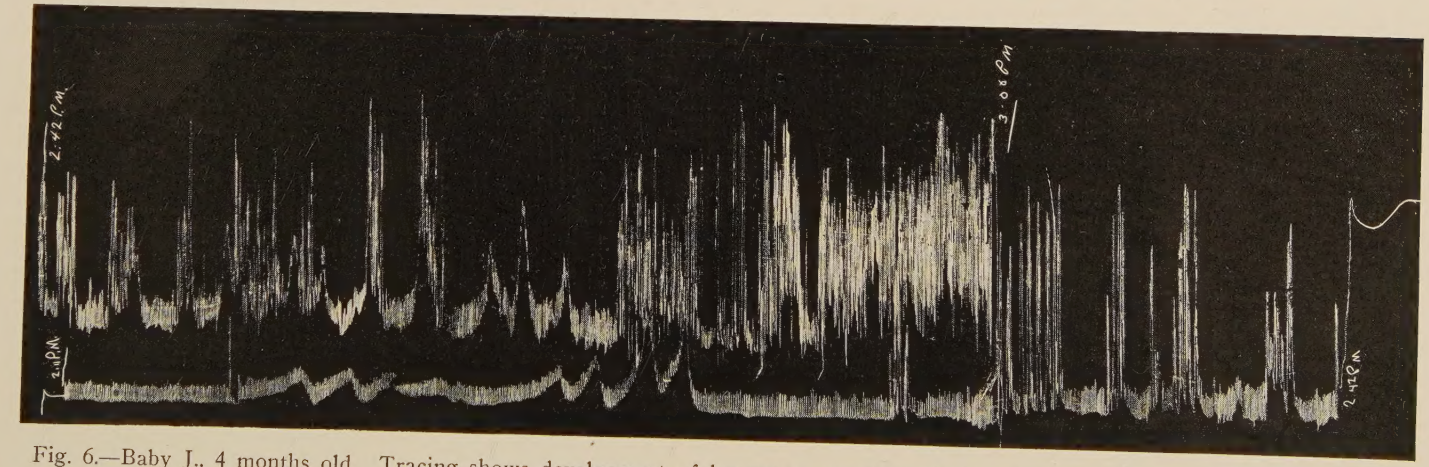

Fig. 6.—Baby J., 4 months old. Tracing shows development of hunger contractions during the interval following a feeding.

that the nervous apparatus for the inhibition of the gastric hunger movements may likewise be immature. Or the tissue hunger may be so great as to overcome any but the strong inhibition of a heavily laden stomach and duodenum.

The vagi form the sensory pathway from the stomach to the brain. The first reflex centers are the sensory nuclei of the vagi in the medulla. A second center, possibly that for conscious hunger, is located in the optic thalami. Rogers has shown that the picking reflex in the pigeon (analogous to the sucking reflex in the babe) is abolished on removal of the thalami.

The reflex irritability (as indicated by the knee jerk) is increased synchronously with each hunger contraction (Carlson). No observations have been made on the infant's knee jerks during the hunger state; but Zybell has shown that the electrical irritability increases during the first eighteen hours of starvation.

Let us summarize the events from the close of one meal till the end of the next. The infant sleeps. The upper stomach musculature maintains a tonic grasp on the contained food. The pyloric antrum is traversed by peristaltic waves (Cannon). The stomach gradually empties. The point of origin of the peristaltic waves rises higher and higher. The tonus rhythm of the fundus begins. The stomach empties itself more completely, the tonus rhythm becomes more intense, and the first hunger contractions appear (Rogers and Hardt).

The first contraction period is apt to be short. After a wait of perhaps twenty minutes a longer and more intense hunger period arrives; then another and another. The infant's sleep becomes lighter. He is more easily awakened by external stimuli or by gastric discomfort. He is put to the breast, nurses vigorously, becomes fatigued (Schmidt, Cramer, Pfaundler), or experiences satiety from distention (Neisser and Bräuning) and again goes to sleep.

What constitutes the hunger state? Does it result from the summation of impulses with an increasing psychic and reflex irritability? The evidence is to the contrary. The increase in the reflex excitability is synchronous with the contraction phase of the stomach, and is absent in the intervals between the contractions. In the infant who has been some hours without food the hunger contractions are nearly continuous, and it would be expected that the reflex excitability would be nearly continuously high.

In the absence of hunger contractions the infant often sucks vigorously on the tube attached to the balloon. The receptive mechanism for the institution of the sucking reflex is so delicate that it is impossible to provide, artificially, a minimal stimulus. During the hunger state, when presumably a rapid succession of hunger contractions maintains a low reflex threshold, there may often be observed a succession of

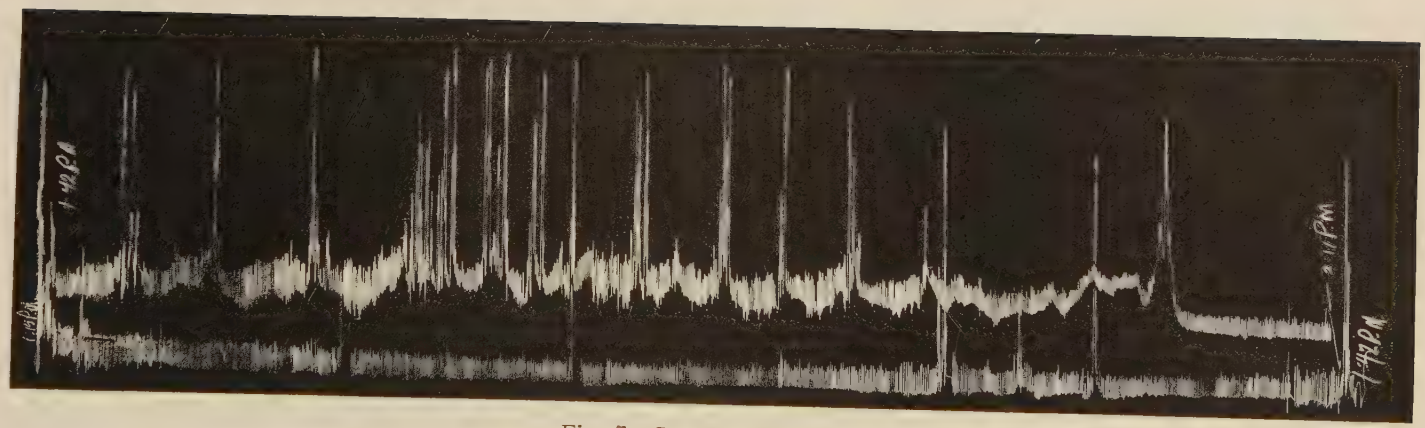

Fig. 7.—Same as Figure 6.

automatic sucking movements involving the lips, tongue and lower jaw, each movement providing the necessary stimulus for its successor.

The lay mind is prone to think that the crying infant is hungry. Comby and Czerny and Keller believe that hunger is a minor cause of crying. Rosenstern notes that in hunger young babies are usually quiet, but that the older infants cry more. Schlossmann remarks that the normal infant endures hunger well.

Observations on this point extending over sixteen months of study of the hunger sensation lead me to believe that in normally thriving breast fed infants, except when more than three or four hours have elapsed since the last feeding, neither the hunger contractions themselves nor the increased irritability due to them are ordinarily immediate factors in the production of crying. Young infants sleep throughout strong contraction periods. Older infants often do the same, and are frequently quiet even from twelve to sixteen hours after a feeding. Mental factors produce crying at a very early age. And the fact that crying ceases when food or water is administered may only mean that the infant's attention is diverted to the performance of a pleasurable act.

It may be noted in this connection that the 2-year-old boy was happier when allowed to take food into his mouth, and that his outlook on life was much more cheerful on days when he could take nourishment by mouth than on other days when the esophageal constriction increased, and it became necessary to introduce the food through the gastric fistula. This feeding through the fistula was without pain, and the child submitted to it with some pleasure.

What is the time interval between feeding and the first appearance of gastric hunger contractions? Ginsburg, Tumpowsky and Carlson studied this point in thirty normal breast fed infants under 4 weeks of age. They gave no data as to gain in weight and did not determine the amount of food taken, but stated that the babes nursed till satisfied. They found the average time between nursing and the appearance of hunger contractions to be two hours and forty minutes, with a minimum of two hours and twenty minutes and a maximum of three hours and thirty minutes. My observations on twelve new-born infants under like conditions yielded these results; a minimum of one hour and thirty minutes, a maximum of three hours and thirty minutes, and an average of about two and one-half hours.

Many infants in the first two weeks do not receive a sufficient supply of breast milk. This is particularly apt to be true of the time the babe and the mother remain in the hospital. Consequently, observations made under the conditions so far outlined may be misleading. Table 1 (A, B and C) gives the results of all satisfactory tracings obtained from normally thriving babies on whom sufficient data as to food intake and weight gain were obtained.

TABLE 1.—Interval for Development of Hunger

A. PREMATURE INFANTS

Name	Age, Days	Food	Feeding Interval	Quantity at Feeding	Interval Before Tracing	Time for Development of First Hunger Period	Remarks
Sw.	7	Breast milk	4 hours 5 times a day	35 c.c.	None	40 min.	Premature Wt. 2,140 gm.
Sw.	11	Breast milk	4 hours 5 times a day	50 c.c.	20 min.	1 hr., 20 min.	Wt. 2,240 gm.
Sw.	20	Breast milk	4 hours 5 times a day	90 c.c.	52 min.	2 hours	Wt. 2,470 gm.
Sw.	25	Breast milk	4 hours 5 times a day	75 gm.	38 min.	1 hr., 50 min.	Wt. 2,565 gm.
St.	13	Breast milk	4 hours 5 times a day	30 c.c.	None	1 hour	Premature Wt. 2,270 gm.
St.	14	Breast milk	4 hours 5 times a day	50 c.c.	None	40 min.	Wt. 2,280 gm.
St.	25	Breast milk	4 hours 5 times a day	90 c.c.	1 hr., 13 min.	1 hr., 15 min.	Wt. 2,450 gm.
St.	28	Breast milk	4 hours 5 times a day	90 c.c.	38 min.	1 hour	Wt.
St.	36	Breast milk	4 hours 6 times a day	100 c.c.	32 min.	1 hr., 50 min.	Wt. 2,720 gm.
Fre.	9	Breast milk	4 hours 6 times a day	45 c.c.	1 hr., 38 min.	1 hr., 38 min.	Premature Wt. 1,380 gm.
Fre.	15	Breast milk	4 hours 6 times a day	45 c.c.	1 hr., 18 min.	1 hr., 18 min.	Wt. 1,530 gm.
Fre	16	Breast milk	4 hours 6 times a day	45 c.c.	23 min.	1 hr., 15 min.	Wt. 1,535 gm.
Fre	21	Breast milk	4 hours 6 times a day	65 c.c.	2 hours	2 hr., 20 min.	Wt. 1,710 gm.

B. FULL TERM NEW-BORN INFANTS

H.	8	Breast milk	4 hours 5 times a day	?	1 hr., 22 min.	3 hr., 50 min.	Wt. 3,590 gm.; gain in 4 days, 90 gm.
Dav.	8	Breast milk	3 hours 8 times a day	75 gm.	1 hr., 55 min.	2 hr., 25 min.	Wt. 4,160 gm.; gain in 5 days 260 gm.; 10 c.c. of milk clot removed from stomach 1 hr. after beginning of hunger contractions
Dav.	9	Breast milk	4 hours (for preceding 24 hours) 5 times a day	?	2 hr., 30 min.	2 hr., 30 min.	Wt. 4,200 gm.; gain in 6 days, 300 gm.; ½ c.c. thick mucus removed from stomach ½ hr. after beginning of hunger contractions
Wes.	8	Breast milk	4 hours 5 times a day	100 gm.	1 hr., 30 min.	3 hr., 10 min.	14 hours fast previous to last feeding
A.	9	Breast milk + cow's milk } aa 8% lactose }	3 hours 8 times a day	70 gm.	1 hr., 45 min.	2 hr., 10 min.	Wt. 3,610 gm.; gain in 6 days 230 gm.; 20 c.c. of thick soft milk clot removed from stomach 50 min. after beginning of hunger contractions
A.	10	Breast milk + cow's milk } aa 8% lactose }	.....	70 gm.	1 hr., 52 min.	2 hours	15 c.c. of fluid and curds removed from stomach 30 min. after beginning of hunger contractions
Wal.	10	Breast milk	4 hours 5 times a day	95 gm.	1 hr., 30 min.	4 hours	Wt. 3,240 gm.; gain in 6 days, 260 gm.
D.	12	Breast milk	4 hours 5 times a day	115 gm.	2 hr., 30 min.	2 hr., 30 min.	Wt. 3,720 gm.; gain in 7 days, 400 gm.

C. NORMAL INFANTS OVER TWO WEEKS OF AGE

Gor.	18	Breast milk	4 hours 5 times a day	85 gm.	2 hr., 23 min.	4 hours	Wt. 3,500 gm.; gain in 13 days, 70 gm.
Gor.	19	Breast milk	4 hours 5 times a day	110 gm.	1 hr., 58 min.	3 hr., 25 min.	
	Mos.						
Way.	3.5	Buttermilk + flour + saccharose	4 hours 5 times a day	150 c.c.	2 hr., 27 min.	3 hr., 12 min.	Wt. 4,960 gm.; gain in 7 days, 440 gm.
Way.	3.5	Buttermilk + flour + saccharose	4 hours 5 times a day	150 c.c.	57 min.	3 hr., 20 min.	40 c.c. of thick white materal removed from stomach 20 min. after beginning of contraction period
Way.	3.5	Buttermilk + flour + saccharose	4 hours 5 times a day	150 c.c.	2 hr., 3 min.	4 hr., 35 min.	
Herm.	4	Breast milk	2 or 3 hours irregular	?	2 hr., 45 min.	3 hr., 30 min.	Well nourished; gaining in weight; normal baby; cared for at home; not in hospital
J.	4	Breast milk	5 times a day	?	2 hr., 15 min.	3 hr., 30 min.	Well nourished; gaining in weight; normal baby; cared for at home; not in hospital
Ad.	4	Malt soup	4 hours 5 times a day	125 c.c.	2 hr., 37 min.	3 hr., 30 min.	Wt. 3,500 gm.; gain in 2 weeks, 200 gm.; prematurely born; 1,600 gm. at birth

The time required for the development of hunger in the premature infant is noticeably short. In the case of the full term new-borns the figures obtained agree fairly well with those given by Ginsburg, Tumpowsky and Carlson, but are definitely greater than those obtained by me (mentioned in a preceding paragraph) from infants whose food intake was not accurately known.

The time required for the development of hunger in any one infant is fairly constant over a short period of time, provided the amount and kind of food is not changed. This conclusion rests not only on the results shown in Table 1, but on a dozen other observations on infants whose feeding conditions remained constant during the time in which studies were made.

With the older infants difficulty in maintaining quiet, after the insertion of tube and balloon, limits the number of observations which give positive evidence as to the first appearance of hunger contractions. Many less successful observations on healthy, normally developing infants yield this negative evidence that in such infants more than a month old I did not observe the development of hunger before the end of three hours.

It should be noted further that the contraction period, the first appearance of which is recorded in Table 1, is the first one to develop after feeding. This period is usually short and is not made up of forceful contractions. With Infants J. and A. more intense and more nearly continuous contractions did not begin for four and four and a half hours, respectively.

Habits as to feeding interval affect the time required for the development of hunger chiefly as they influence the emptying time of the stomach. It has been shown that the speed of gastric emptying is proportional to the length of time during which the individual has been without food (Tobler, Haudek and Stigler), and that large feedings are emptied with relatively greater rapidity than small ones (Tobler and Bogen). Habits undoubtedly exert a more powerful influence on the mental factors associated with appetite than on hunger itself.

Tables 2, 3 and 4 illustrate the shorter time required for the development of hunger in infants with chronic nourishment disturbance, and indicate that the presence of hunger contractions is not in itself evidence that the stomach is ready for food.

In the columns headed "Remarks" in Tables 1, 2, 3 and 4, there are notes as to material recovered with the stomach tube after the onset of gastric hunger contractions. In normal babies, however, there probably does exist a relation between the emptying time of the stomach and the interval for the development of hunger.

Observations on the emptying time in infants, so far reported, have been made either with the relatively stiff catheter, the stomach tube,

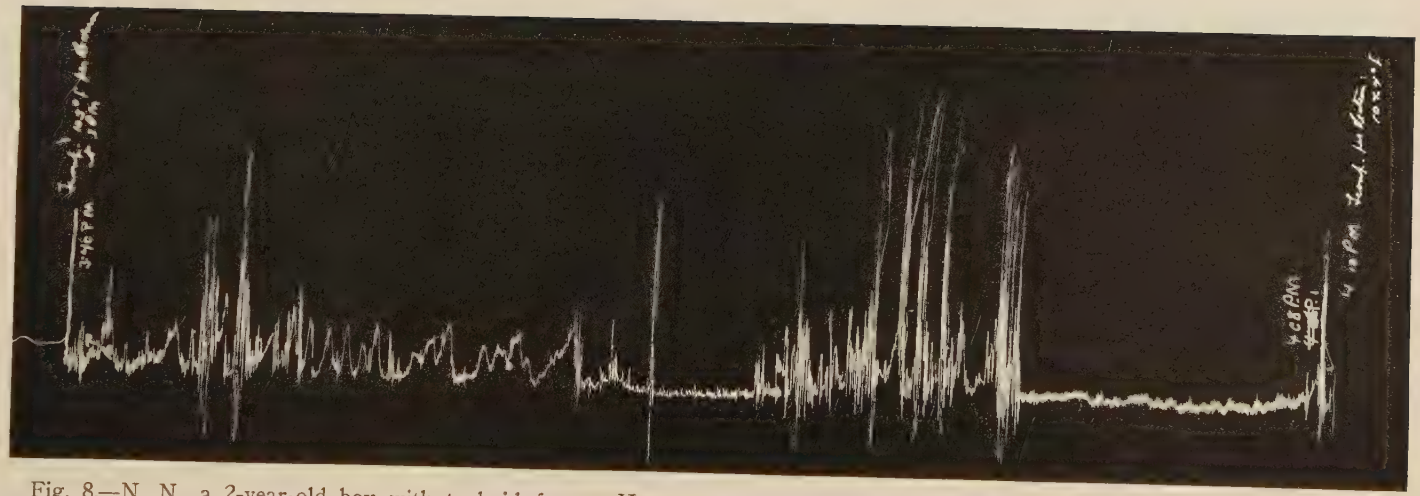

Fig. 8.—N. N., a 2-year-old boy with typhoid fever. Hunger contractions present when rectal temperature ranges between 104.4 and 105 F.

or the Roentgen ray. The flexible tube introduced by Rehfuss should replace the catheter for this purpose; it was used in my work. The literature contains no reports of the time required for gastric digestion in the premature infant. The emptying time in normal breast-fed infants under 1 week is usually less than one hour (Leo). The Roentgen-ray observations of Ladd and of Tobler and Bogen would indicate that in normal breast-fed infants the stomach is frequently not empty until after two to three hours. The figures obtained with the use of the stomach tube by Epstein, Czerny, Keller and Cassel indicate a delayed emptying time in gastro-intestinal disease.

TABLE 2.—Hunger in Atrophy Resulting from Continued Starvation

N. N., aged 2 years; gastric fistula; weight fluctuating between 6,800 gm. and 7,200 gm.; typhoid fever Dec. 1 until Dec. 14, 1916.

Date 1916	Food	Time of Last Feeding	Beginning of Ttracing	
10/19	Diluted cow's milk + general diet	6 a. m.	10:15 a. m.	Practically continuous hunger periods until 10:50 a. m.
10/20	Diluted cow's milk + general diet	10 a. m.	2:12 p. m.	Practically continuous hunger periods until 3:15 p. m.
11/ 1	.....	10 a. m.	2:16 p. m.	One hunger period at 2:45 p. m. to 2:50 p. m. Hunger contractions practically continuous after 3 p. m. until 4:50 p. m.
11/10	160 c.c. cow's milk at preceding feeding	2 p. m.	2:45 p. m.	Observations continued until 5:10 p. m. No hunger periods, but child cried or was restless over half of the time
10/11	160 c.c. cow's milk at preceding feeding	2 p. m.	9:00 p. m.	Practically continuous contractions until 11 p. m.
11/11	200 c.c. protein milk + 7% dextrimaltose	5 p. m.	10:12 p. m.	Practically continuous contractions until 11 p. m.
11/12	200 c.c. protein milk + 7% dextrimaltose	5 p. m.	8:41 p. m.	First hunger period at 9:30; practically continuous from 9:45 on until 10:44 p. m.
11/29	200 c.c. protein milk + 7% dextrimaltose	1 p. m.	4:02 p. m.	First hunger period began at 4:35 p. m.; practically continuous from 5 p. m. on until 5:42 p. m.
12/27	200 c.c. protein milk + 7% dextrimaltose + cereals	9 a. m.	12:34 p. m.	Hunger periods practically continuous until 1:30 p. m.
12/28	200 c.c. protein milk + 7% dextrimaltose + cereals	9 a. m.	12:22 p. m.	Hunger periods began about 12:50; hunger periods became continuous after 1:20 p. m.
12/30	200 c.c. protein milk + 7% dextrimaltose + cereals	5 a. m.	10:13 a. m.	Practically continuous hunger periods until 11:20 a. m.

Major, using the Roentgen ray, finds the emptying time delayed in dyspepsia, but accelerated in decomposition. With the same method Pisek and LeWald found the emptying time to be shorter in infants with chronic disturbances of nutrition.

These last findings, taken in conjunction with the already quoted reports of Tobler, and of Haudek and Stigler, that the emptying time is shortened by hunger, are suggestive of the results here obtained experimentally; that is, the greater gastric hunger contraction in infants with chronic nourishment disturbance.

Not only is the interval for development of hunger shorter in such infants, but the contractions become much more intense. Nov. 10,

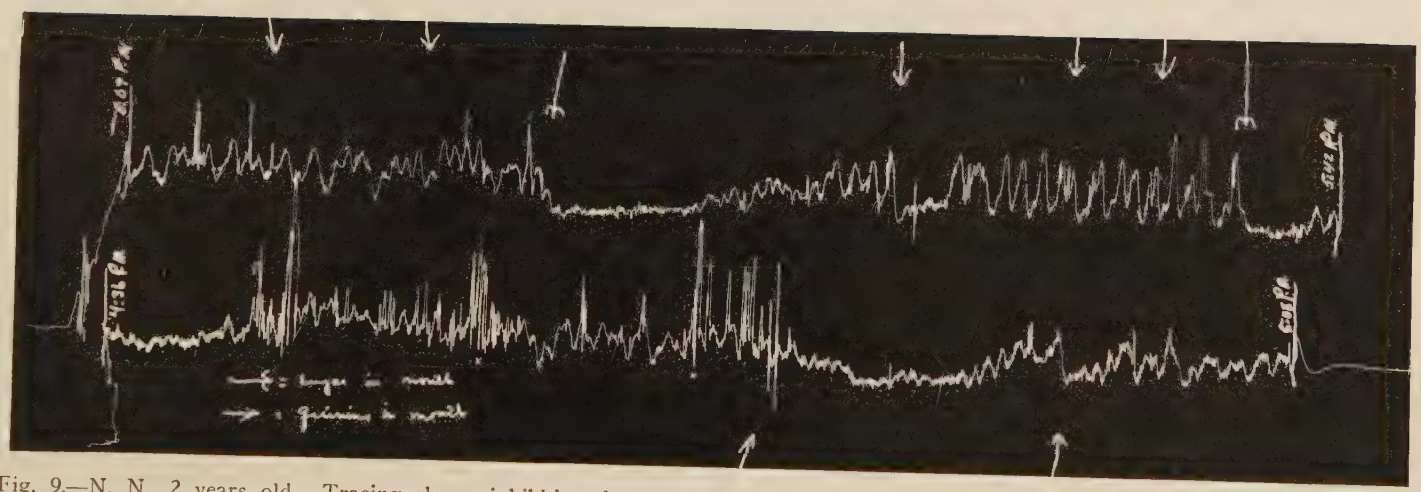

Fig. 9.—N. N., 2 years old. Tracing shows inhibition from sugar in the mouth; absence of inhibition from quinin in the mouth.

1916, the 2-year-old boy (Table 2), whose weight in spite of a calorically sufficient intake had remained stationary, and whose temperature had been irregular, developed fever and diarrhea. After eight hours of starvation, with temperature normal, the graphic record of his gastric activities resembled those of the starving pigeon and of the premature infant already mentioned. The contractions were continuous and required only twelve seconds for their completion. Next day the child was put on protein milk and thereafter improved.

It is generally agreed that mixtures with high fat content leave the stomach most slowly, while those with low fat and high carbohydrate

TABLE 3.—Hunger in Exudative Diathesis

Aus., 7 weeks old, Dec. 19, 1916. Feeding interval 4 hours, 5 times a day.

Date	Weight, Gm.	Food: Breast Milk + Buttermilk + Flour + Saccharose, C.c.	Time of Last Feeding	Beginning of Tracing	
12/19/16	4,450	100	1 p. m.	3:28 p. m.	Hunger contractions began at 3:30 p. m. Hunger contractions continuous from 3:55 to 4:37 p. m.
12/22/16	4,460	100	9 a. m.	11:49 a. m.	Hunger contractions present at 11:49 a. m. Hunger contractions continuous until 12:50 p. m.
12/22/16	4,460	150	1:15 p. m.	3:34 p. m.	Hunger contractions began at 5:45 p. m.
1/ 6/17	4,640	125	8 a. m.	10:55 a. m.	Hunger contractions began at 10:55 a. m. Hunger contractions continuous until 12:21 p. m.
1/ 8/17	4,640	125	8:40 a. m.	11:51 a. m.	Hunger contractions began at 12 m. Hunger contractions strong and continuous after 12:18. Babe was restless
1/11/17	4,650	125	8:45 a. m.	11:11 a. m.	Hunger contractions present by 11:45 a. m. Hunger contractions continuous until 1:35 p. m.
1/13/17	4,740	150	8:20 a. m.	11:03 a. m.	Hunger contractions began at 11:45 a. m. Hunger contractions continuous from 12 to 1 p. m.
1/15/17	4,770	150	8:45 a. m.	11:01 a. m.	Hunger contractions present at 11:20 a. m. Hunger contractions continuout from 11:30 a. m. until 12:50 p. m.
1/15/17	4,770	150	12:50 p. m.	3:21 p. m.	Babe cried a large part of time; no evidence of hunger periods until 5 p. m.

leave most rapidly. In Infants A. and W. the time interval for the development of hunger contractions was much longer when they received low fat and high carbohydrate, and shorter when they received high fat and low carbohydrate. This would be paradoxical if the gastric hunger contractions depended exclusively on the emptying time.

It is, then, only in normal babies, receiving well tolerated food in sufficient quantity, that the development of hunger waits on the emptying of the stomach.

The interval necessary for the development of hunger depends in part on the form of nourishment and is shortest with that food which least satisfies the infant's tissue need (Table 4). The question as to whether the rapid development of hunger in qualitatively poorly

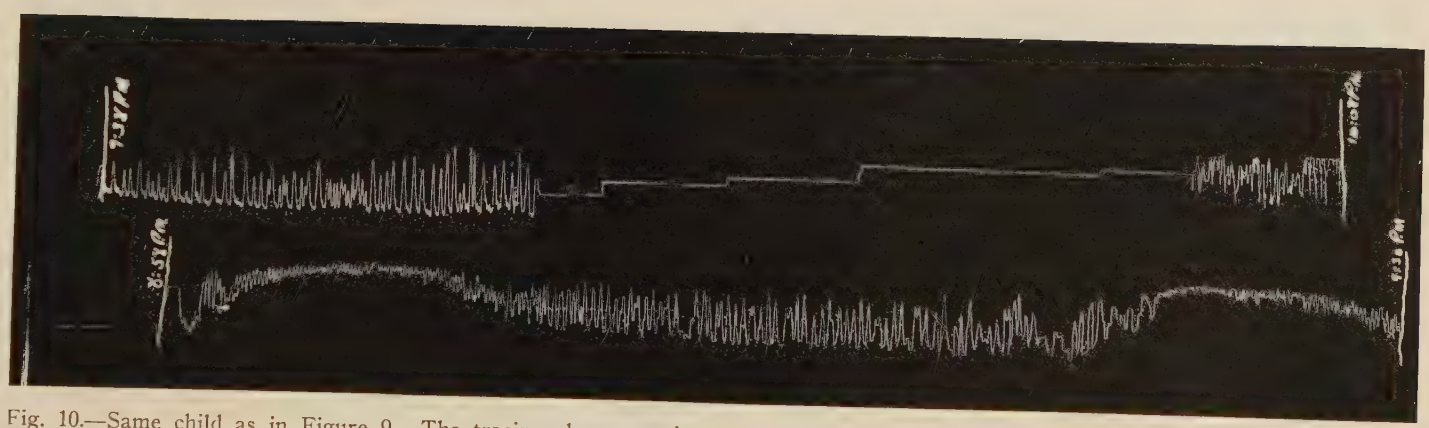

Fig. 10.—Same child as in Figure 9. The tracing shows continuous short contractions in atrophy; after eight hours of starvation.

nourished infants depends on the administration of food deficient in carbohydrate in particular, or on the giving of food poorly tolerated in general, is not answered. Records of the gastric contractions in infants suffering from the chronic nourishment disturbance due to long continued carbohydrate overfeeding (the "Mehlnährschaden" of Czerny) would help to settle this point.

TABLE 4.—Interval for Development of Hunger in Infants with Chronic Disturbance of Nutrition and Showing Influence of Change in Form of Nourishment

Name and Date	Age, Mo.	Diagnosis	Weight, Gm.	Food	Interval Before Tracing	Time for Development of First Hunger Period	Remarks
Til.	3	Atrophy.....	Stationary 4,080	120 gm. protein milk + 7% dextrimaltose 5 times a day	.....	.....	Hunger periods with partial tetanus less than 3 hours after feeding
Ad. 2/26/17	4	Chronic alimentary disorder due to overfeeding with milk	3,300	150 c.c. ½ milk + 10% saccharose 5 times a day	.....	.....	Hunger contractions present in 2 hours and 20 minutes
Ad. 3/ 8/17	4	Chronic alimentary disorder due to overfeeding with milk	3,500	125 c.c. malt soup 5 times a day	.....	.....	Babe improved clinically; hunger contractions first appear in 3½ hrs.
Way.	3	Chronic nourishment disturbance with eczema	.....	Mixture containing 8% fat. Feeding intervals short and irregular. After entrance to hospital fed 5 times a day	.....	.....	Entered hospital April 14, 1917
4/14/17	..	.....	4,200	150 c.c. ½ cow's milk + 10% saccharose	2 hr., 7 min.	2 hr., 7 min.	Stomach emptied 3 hours after feeding; ½ c.c. of mucus and thick curd obtained
4/23/17	..	.....	4,510	150 c.c. ½ cow's milk + 10% saccharose	2 hr., 10 min.	2 hr., 10 min.	Eczema increased; 40 c.c. of clotted milk and clear thin fluid recovered from stomach 3 hours and 25 minutes after feeding
5/ 1/17	..	.....	4,960	150 c.c. buttermilk + flour + saccharose	2 hr., 3 min.	4 hr., 35 min.	Eczema has disappeared
5/ 2/17	..	.....	4,960	150 c.c. buttermilk + flour + saccharose	2 hr., 27 min.	3 hr., 12 min.	
5/ 3/17	..	.....	4,960	150 c.c. buttermilk + flour + saccharose	57 min.	3 hr., 20 min.	40 c.c. of thick white material removed from stomach 20 minutes after beginning of first contraction period

Attention has already been called to the heightened electrical reactions found by Zybell in hungry infants. I also wish to mention the findings of Finklestein, Thiemich and Japha that the electrical irritability is frequently heightened in artificially fed infants, and of Czerny and Moser that there is an increase in the electrical irritability of infants suffering with "Mehlnährschaden." It is possible that the heightened electrical irritability in all depends on the increased hunger contractions due again in part to the constant chemical stimulation reaching the stomach from the semistarved tissues.

Most premature infants and many young infants nurse poorly. The consequent effect on lactation and on the babe's nourishment is serious. An extensive literature on this subject has been developed in German, but there is surprisingly little in French and in English.

In 1888 Auerbach described the infantile manner of sucking, which depends on the chewing muscles, and Escherich showed its teleologic importance. The reflex paths and center in the medulla were demonstrated in 1894 (Basch). Cramer, Suszwein, Finklestein, Rott, Rosenstern, Barth and Kasahara have further studied the question and report results which in general support the theory that the inability to nurse well is to be attributed primarily to an imperfect nervous mechanism and not to muscular weakness.

For further elucidation of the question, tracings of the movements of the empty stomach were taken in two infants who were extreme examples.

The first baby (Baby M.), weighing 2,700 gm. at birth and presenting no anatomic peculiarities, took very little from the mother's breast during the first three weeks, although sufficient milk was expressed therefrom to feed the baby and to complement the feedings of other babies.

The second infant (Baby T.), aged 3 months, had weaned himself from the breast, had developed dyspepsia and atrophy on artificial feeding, and could be made to take his food from the bottle only with great difficulty. He seemed able to fix his attention on anything other than the act of feeding.

In these infants as well as in the five prematures, and in one typical case of congenital myxedema, hunger contractions of at least normal force and duration were present. At the time they were studied, none of the infants was able to nurse successfully. In all, the sucking reflex was qualitatively present.

This study does not solve the problem as to the causation of feeble nursing, but does limit the field of possibilities by excluding derangements of the primitive hunger apparatus.

Carlson reports Rupp's finding that hunger contractions persist during the fever excited by the administration of typhoid vaccine. The boy with the gastric fistula contracted typhoid fever from a carrier. Tracings taken while his rectal temperature ranged between 104.4 F. and 105 F., show the presence of hunger contractions.

Carlson and Ginsburg found hypertonicity and hypermotility in the stomachs of two infants with pylorospasm and stenosis. From a six weeks' old infant (Baby S.) with pyloric stenosis, I obtained records which agree with Carlson and Ginsburg's description of periods of tetanus lasting several minutes interspersed with vigorous contractions of normal duration.

Carlson suggests that pylorospasm and stenosis may be an expression of gastric hypermotility. His cases were seen late, as was the one here reported. In the absence of tracings taken at the beginning of the disease, it is likely that the hypermotility results from the inanition following the obstruction at the pylorus. And without definite knowledge that the stomach was washed empty, the long periods of tetanus observed may represent the so-called visible gastric peristalsis.

SUMMARY

The study of fifty-six infants from birth to 2 years of age gives the following results:

1. Confirmation of previous work, that hunger contractions are greater in the new-born infant, with description of these contractions.

2. Determination of the still greater hunger contraction in the stomachs of prematurely born infants, with description of these contractions.

3. There is no relation between cyanosis and hunger contractions.

4. Inhibition of the hunger contractions from the mouth does not occur in young infants.

5. Inhibition of the hunger contractions from the mouth in older infants is present only as the result of stimuli, which the babe has learned to recognize as food. It does not occur with substances producing equally strong sensory impressions, but which are not considered by the infant as food.

6. Inhibition from the mouth is psychic in character.

7. Reflex inhibition from the presence of food in the stomach is present in infants of all ages.

8. This reflex inhibition from the stomach may be only partially developed in young infants.

9. Successive automatic sucking movements — each sucking act serving as the stimulus for its successor — are present during the hunger state, when the reflex threshold is kept almost constantly low by a rapid succession of hunger contractions.

10. In normally developing breast fed babes, hunger is not ordinarily an immediate cause of crying.

11. The average time required for the development of hunger in healthy infants gaining in weight and receiving a known sufficient amount of food is, in prematures, under one month, one hour and forty minutes, with a maximum of two hours and twenty minutes and a minimum of forty minutes; in full term infants under two weeks, two hours and fifty minutes, with a maximum of four hours and a minimum of two hours; in infants from two weeks to four months,

three hours and forty minutes, with a maximum of four hours and thirty-five minutes and a minimum of three hours and twelve minutes (Table 1).

12. The time required for the development of hunger in any one infant is fairly constant over a short period of time provided the amount and kind of food is not changed (Tables 1, 2, 3 and 4).

13. The time required for the development of hunger in infants with chronic nourishment disturbance is shorter than in normal infants (Tables 2, 3 and 4).

14. The time required for the development of hunger is shorter when the infant receives food which is poorly tolerated (Table 4).

15. Hunger contractions occur in these infants long before the stomach has emptied. Consequently their presence is not in itself an indication that the stomach is ready for food.

16. The feeble nursing exhibited by most prematures and by many older infants is not due to derangement of the primitive hunger apparatus. Hunger contractions are present and of normal intensity in such infants.

17. Hunger contractions were present in one infant with congenital myxedema.

18. Hunger contractions were present in a 2-year-old boy with typhoid fever when the rectal temperature ranged between 104.4 F. and 105 F.

19. Confirmation of previous findings of increased hunger contractions in infants with pyloric stenosis.

I wish to express my sincere thanks to Dr. A. J. Carlson of the University of Chicago for suggestions which aided materially in carrying out these studies; to Dr. E. P. Lyon and Dr. A. D. Hirschfelder for the loan of apparatus from the departments of physiology and pharmacology; to Dr. F. H. Scott and Dr. F. B.. Kingsbury for advice and assistance in the construction of apparatus; to Dr. F. W. Schultz for the use of material from the Infant Welfare Clinic; to Dr. N. O. Pearce, teaching fellow in pediatrics, and to head nurses Barber and Wenck, who cheerfully assisted in preparing the little patients for examination.

To my chief, Dr. J. P. Sedgwick, who first suggested this problem, and who allowed the free use of his material in the service at the university hospitals, I wish to express my grateful appreciation for constant stimulating interest and helpful suggestions.

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HUNGER AND APPETITE SECRETION OF GASTRIC JUICE IN INFANTS' STOMACHS *

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There is apparently a gastric element in appetite. The contractions of the stomach institute hunger. Its profuse and rich secretion causes an entirely different sensation — not painful, but pleasant. Carlson concludes that the appetite or psychic gastric juice described by Pawlow[1] stimulates sensory nerve endings in the gastric mucosa. The resulting sensation resembles that which follows the first few mouthfuls of good food at a meal to which one has come hungry, and directs the flow of consciousness toward the matter of taking food.

Pediatric literature contains many references to this secretion. Bauer and Deutsch found no gastric juice in the baby's stomach after it had reached eagerly for its bottle. Pfaundler noted that in babes who nursed actively the stomach emptied sooner, and the degree of acidity attained was higher than in babes who were fed passively or through the tube. Cohnheim and Soetbeer, working with gastrotomized new-born pups, obtained juice containing hydrochloric acid even when the pups nursed on nonlactating breasts. A. H. Meyer found a great variation in gastric acidities in the same child and conjectured that the variations might depend on the presence or absence of Pawlow's appetite juice. Schmidt writes that the infant on the breast works and stimulates the secretion of gastric juice. Meisl advocates the use of a pacifier before meals to cause the flow of appetite juice. Bogen, whose material included a 3½-year-old boy with a stenosed esophagus and gastric fistula, concludes that psychic secretion of gastric juice does occur. Nothmann, in 1909, formally investigated the question of the secretion of appetite juice by the infant's stomach, and concluded that it took place even immediately after birth. Rosenstern advised the use of pepsin and hydrochloric acid to stimulate the appetite of infants who nurse poorly. Bönniger could find in pups no relation between the kind of food and the secretion of gastric juice.

With the exceptions of the work done on pups, and Bogen's work on a 3½-year-old boy, the foregoing is all brought into question because it relies on the use of the ordinary catheter or stiff stomach tube, which

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1. References to the literature will be found at the end of the article.

does not permit accurate quantitative studies. A still more serious criticism, and one which leaves the whole subject open, is that in none of the quoted work is the possibility of a continuous secretion of gastric juice sufficiently taken into account.

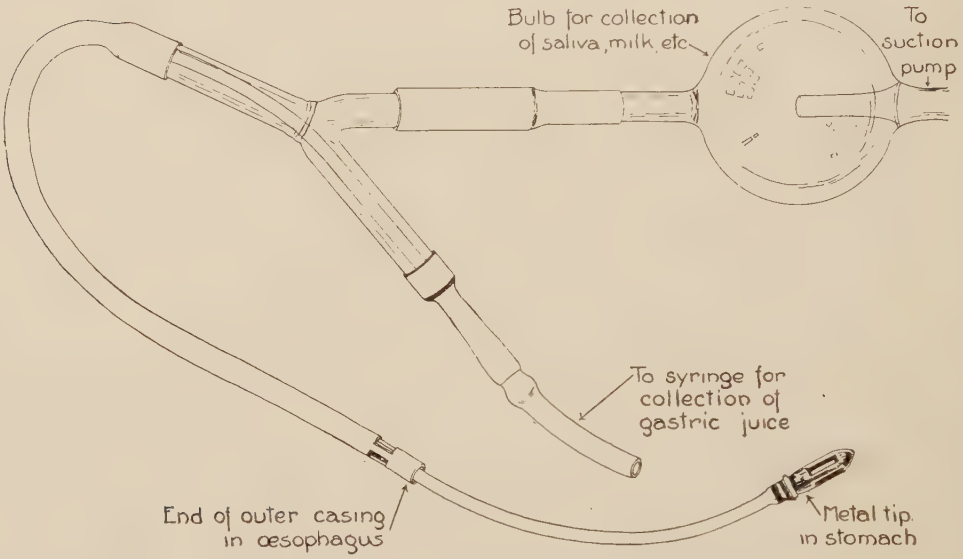
In 1888 Leo found free hydrochloric acid in the stomachs of unfed new-born babes, and noted that in older infants the stomach was rarely entirely empty, so that he could usually recover a few drops of thick, yellowish acid fluid. He washed out the stomach and again inserted the tube and then obtained only wash water from the preceding washings. Consequently Leo concluded that the acid juice obtained by him from the "empty" stomach was the gastric juice remaining from the last meal, concentrated by the absorption of water. Wohlmann reported that the secretion of the infant's empty stomach is viscid, colorless, glassy, and without free hydrochloric acid. Wohlmann took his specimens from one to two hours after feeding. The teachings of Pawlow that gastric secretion depends on appetite or on food or other stimuli in the stomach impressed the medical mind so deeply that until the present decade all gastric secretion was interpreted in the light of his investigations. A. H. Meyer concluded that the passage of the stomach tube does not excite the secretion of acid gastric juice. Pawlow's published work supports the same conclusion. Engel reports a 4-week-old babe with pyloric stenosis and a jejunal fistula. From this infant, who was fed through the fistula, Engel obtained by way of the esophagus from 60 to 200 c.c. of gastric juice daily. The total acidity of this juice ranged from 60 to 70 and was nearly entirely made up of free hydrochloric acid. Engel was unable to explain his findings except on the basis of a pathologic hypersecretion, which he thought might have caused the pyloric stenosis. Alfred F. Hess, in 1913, showed that the stomach of the unfed new-born babe secretes a highly acid juice, and he concluded further that saliva does not act as a stimulus to the production of such juice. He was unable to determine a relationship between the amount of sucking and the amount of juice secreted. Sedgwick recovered acid stomach and duodenal contents three and four hours after nursing. In 1905 Boldyreff reported continuous secretion of the gastric glands in starving dogs. Ten years later Fowler, Rehfuss and Hawk concluded that, in man, the gastric glands are never idle, while Carlson demonstrated the continuous secretion of gastric juice in the empty stomach of normal adults. Referring to its secretion during the hunger state, Carlson calls it hunger juice.

It is evident that the determination of the secretion of an appetite juice in the infant's stomach must be made in conjunction with the determination of its continuous secretion.

The flexible tube with the slotted weight at the tip described by Rehfuss, combined with any simple syringe for gentle aspiration, makes

an excellent instrument for the study of the physiology of the stomach of the infant. A smaller tip can be made for those infants who cannot swallow the ordinary tip. With this apparatus I have repeatedly recovered from the infant's stomach the entire 30 to 50 c.c. of water introduced into it and never have lost more than 2 c.c. in the washing. Furthermore, large, thick, gelatinous clumps of mucus and curd are removed without difficulty.

In order to avoid, as far as possible, contaminating the gastric juice with saliva, and to permit the carrying out of sham feeding, I converted a No. 21 F. soft rubber catheter into an outer casing for the Rehfuss tube. When in place this outer casing terminates internally in the esophagus, and externally with a suction apparatus. The whole is explained in the accompanying illustration, which is one-half actual size.


Bulb for collection of saliva, milk, etc.
To suction pump
To syringe for collection of gastric juice
End of outer casing in œsophagus
Metal tip in stomach

Author's apparatus for removing gastric contents from infants; one-half actual size.

The experimental procedure was as follows: If the babe fasted all night, he was given water at 5 a. m. in quantity equivalent to his usual feeding. When the stomach was examined a few hours later, milk remains were never found. If the period without food were shorter, his stomach was thoroughly washed out and observations begun an hour later.

If no aspiration is applied to the stomach tube during the half hour, the amount obtained is usually less than 1 c.c. The usual procedure was to insert the tube, exert suction to empty the stomach of any content, then allow the tube to remain one-half hour without suction, and

collect the specimen, if any. Repeat the procedure, exerting gentle suction every two and one-half minutes and collect the specimen. Exert suction in the same way during a third half hour while the sham feeding progresses. The final two specimens only are listed in the accompanying table.

As a rule, no secretion was obtained for five minutes after the insertion of the tube. On one occasion gastric juice containing free hydrochloric acid was obtained within two minutes of the time at which introduction of the tube began (Baby A.). This is less than the latent time usually required by the gastric glands (Carlson, Pawlow) and is further evidence that the secretion here obtained was not produced artificially by the apparatus.

To stimulate an appetite secretion, the babe was given a pacifier threaded over the tube, or, the food to which he was accustomed was administered by a medicine dropper, or, with the artificially fed babes, from their usual nursing bottle. The infant always sucked vigorously during this procedure. If the babe sucked before sham feeding began, it has been noted in the table. As a rule, the babes slept or were quiet and did not suck, except after the beginning of the sham feeding. The presence of the tube seemed to discommode these babes very little. There certainly was no psychic excitement to depress the action of the gastric glands while the babes were smacking and sucking over their food.

In three cases only, as noted in the table, did food reach the stomach. Strictly speaking, neither these instances nor the specimens which contained blood should be considered as offering evidence on either the subject of "hunger" or "appetite" gastric juice. The only demonstrable effect of the blood, which was never present in more than a trace, was to lower the acid titration values. On the three occasions on which milk reached the stomach, larger amounts of secretion was obtained.

The titrations were done against tenth-normal sodium hydroxid, using di-methyl-amino-azobenzol and phenolphthalein as indicators. The hydrogen-ion concentrations were done by the gas chain method. I wish to thank Dr. J. F. McClendon for his courtesy in allowing the use of his apparatus.

The "appetite" gastric juice is characterized by its relatively profuse secretion and high acidity. Neither characteristic was present in the juice obtained after sham feeding in these infants. On the contrary, the juice obtained differed little in character and quantity from that obtained before sham feeding was begun.

It will be seen that the empty stomach of the infant continuously secretes a juice which at times is as acid as that of the adult, and that the infant's stomach does not secrete an "appetite" or psychic juice.

TABLE 1.—Comparative Secretion of Hunger and Appetite. Gastric Juice

Name	Age	Length of Preceding Starvation, Hours	Behavior During Collection of Continuous Secretion or "Hunger" Juice	Amount of "Hunger" Juice per ½ Hour, C.c.	Description of "Hunger" Juice	Method of Provoking Appetite Juice	Amount of Appetite Juice per ½ Hour, C.c.	Description of Appetite Juice
Ow.	15 hrs.	Unfed	Cried some; slept most of time	0.9	Slightly viscid; trace of saliva; no blood; translucent; free HCl 0; total acid 4			
Wal.	7 days	4	Slept.....	3.0	Thick, viscid trace of saliva; free HCl 8; total acid 18	Sucking on pacifier.....	3.0	Thick, viscid, trace of saliva; free HCl 2; total acid 18
Wal.	9 days	6	Quiet; no sucking...	3.0	Trace of saliva; free HCl 2.5; total acid 17.5			
Wes.	2 hrs.	Unfed	No sucking.....	6.0	$CH+ = 0.3 \times 10^{-2}$; free HCl 50; total acid 60			
Wes.	7 days	13	No sucking.....	1.75	Yellowish, clear, viscid; Gmelin test neg.; free HCl 18; total acid 39			
He.	6 days	11	Slept throughout; sucked a little	1.0	Slightly viscid; no saliva; no blood; free HCl 5; total acid 40			
P.	9 days	12	Slept; no sucking...	1.0	Viscid, clear, no foam; trace of blood; free HCl neg.; total acid 30	Sham feeding: 5 c.c. breast milk; sucked vigorously for 15 minutes	0.5	Thick, viscid, trace of blood; free HCl 0; total acid 30
A.	11 days	12	Slept most of time; no sucking	1.5	Slightly viscid trace of blood; free HCl 60; total acid 80	8 c.c. breast milk; sucked vigorously for 20 minutes	2.5	Brownish, blood stained, slightly viscid; free HCl 54; total acid 60
S.	12 days	13	Cried; no sucking...	2.0	Transparent, slightly viscid; free HCl 55; total acid 75	5 c.c. breast milk; sucked vigorously for 15 minutes	1.0	Thin, transparent, slightly viscid; free HCl 60; total acid 90
H.	17 days	13	Slept most of time; sucked occasionally	2.0	Clear, slightly viscid; trace of blood; free HCl 30; total acid 60	10 c.c. breast milk; sucked on tube	1.0	Clear trace of blood; free HCl 10; total acid 40
K.	3.5 mos.	17	Sucked on tube.....	3.5	Translucent viscid; trace of saliva; free HCl 7; total acid 28	5 c.c. cow's milk + saccharose; sucked	10.0	Clear, viscid, trace of saliva; small amount of milk; free HCl 0
K.	3.5 mos.	17	Sucked constantly	3.0	Trace of saliva; free HCl 33; total acid 38	Cow's milk + saccharose; sucked	2.0	Total acid 24; turbid, blood stained; free HCl 25; total acid 55
Ad.	5 mos.	16	Slept; no sucking...	3.0	Clear viscid, trace of saliva; free HCl 56; total acid 70	Malt soup	8.0	Contained milk; free HCl 18; total acid 45
Ad.	5 mos.	17	Slept; no sucking...	3.0	Thin, clear, slightly greenish; free MCl 80; total acid 110; $CH+ = 0.5 \times 10^{-1}$	15 c.c. malt soup; sucked vigorously 20 minutes	5.0	Contains 0.5 c.c. milk clot; free HCl 10; total acid 45; $CH+ = 2 \times 10^{-1}$
Wi.	7 days	25	Cried much; did not suck	1.0	Thick, viscid trace of blood; free HCl 10; total acid 40	Sham feeding: 10 c.c. breast milk; sucked vigorously; quiet	0.2	Clear mucus; free HCl 0
Ca.	9 days	24	Slept throughout; did not suck	3.0	Turbid, viscid fluid containing trace of blood; free HCl 12; total acid 32	Sham feeding: 10 c.c. breast milk; sucked vigorously; did not cry	0.9	Turbid, viscid, containing partially digested blood; free HCl 22; total acid 55
Ni.	11 days	23	Cried ⅓ of time; sucked a little	1.5	Viscid mucus; free HCl 0; total acid 8	Sham feeding: 10 c.c. breast milk; sucked vigorously; cried a little	1.0	Turbid, viscid, mucus; free HCl 0; total acid 10
P.	1 mo.	25	Slept ½ of time; cried a good deal; no sucking	1.8	Trace of saliva; viscid; free HCl +; total acid 9	Sham feeding: 10 c.c. breast milk; sucked some; cried much	1.0	Viscid mucus; trace of blood; free HCl 10; total acid 16
Wa.	5 mo.	21	Slept most of time; sucked a little	8.0	Clear, slightly viscid; free HCl 72; total acid 90	Sham feeding: 10 c.c. malt soup; sucked vigorously; whined and teased	14.0	Slightly viscid, cloudy; small amount of blood-stained mucus; free HCl 60; total acid 80

This accords with the absence of psychic inhibition of the hunger contractions.

As indicated by the digestion of egg white in Mett's tube, the infant's hunger juice contains pepsin.

Reiche has demonstrated the absence of a duodenal reflux into the infant's stomach. The present findings support his conclusion. What, then, becomes of this continuous secretion under circumstances such as enforced therapeutic starvation from twenty-four to forty-eight hours? Pfaundler has conjectured that at the close of digestion the alkaline secretion of the pyloric glands gradually neutralizes the acid content of the stomach. I cannot support this view. The finding of a greater quantity of juice when a more continuous suction is maintained, the frequent absence of juice when the tube is first inserted, and Sedgwick's finding that the young infant's duodenal contents are acid, favor the conclusion that at least a portion of this juice makes its way into the intestine.

It seems probable, therefore, that the secretion of the alkaline pancreatic and intestinal juices, which in the adult regurgitate into the stomach, as demonstrated by Boldyreff, and lower the acidity of the juice in the stomach (Carlson, Rehfuss and Hawk and Boldyreff), is, in the infant, relatively deficient.

The hunger juice is delivered through the tube intermittently. The most profuse secretion is, as a rule, associated with the higher acidities; this is also true in the adult (Carlson). The largest amounts were obtained from one of the unfed new-born babes and from the older infants. It is readily seen that the stomach of the starving infant can secrete from 50 to 200 c.c., or more, of highly acid juice daily. This equals the amount Engel obtained from his case of pyloric stenosis, which has served as the clinical basis for the theory that hyperacidity or hypersecretion of the gastric juice is an etiologic factor in that disease.

Furthermore, this demonstration of the capacity of the infant's stomach to secrete a highly acid juice, makes it probable that the low acid values found during gastric digestion of milk are in part due to its binding power for acid (Aron), and in part due to the relatively slight stimulation which it exerts on the gastric glands (Pawlow, Moore and Allanson). Huenekens found a hydrogen ion concentration of 174×10^{-5} in a 9½-months-old infant after a meal of soup and vegetables. Most of his results were lower, however. No such studies have been made in younger infants.

Experience in the clinic of the University of Minnesota and in other clinics (Rott) has proved the advantage which is gained in feeding the premature infant by tube. Theoretical objections to the use of

the tube have been based principally on the assumed existence of an appetite gastric juice (Pfaundler).

The amount of saliva collected during the experiments on gastric secretion was measured in six cases.

W.— 7 days	No sham feeding	7 c.c. in 40 minutes
H.—17 days	Sham feeding	14 c.c. in 2 hours
P.— 1 mo.	Sham feeding	25 c.c. in 1.5 hours
Ne.—11 days	Sham feeding	15 c.c. in 1.5 hours
P.— 9 days	Sham feeding	8 c.c. in 1.5 hours
S.—12 days	Sham feeding	10 c.c. in 1.5 hours

The saliva collected was the thick viscid product of the submaxillary glands, which Schilling has noted as being preponderant during early infancy.

Allaria points out the chemical and mechanical advantages of having the milk well mixed with saliva, and estimates that the infant secretes an amount equal to from 10 to 20 per cent. of the ingested food. The tube-fed infant may do without this secretion in part or altogether, but there is no evidence that his gastric secretion is less than that of the actively nursing babe.

What light does this study throw on deprivation of food as a therapeutic agent? In infancy such a measure finds its chief field in acute alimentary disorders and summer diarrheas. The significant fact is that in hunger the infant's stomach secretes continuously, but with intermittent intensity, a highly acid juice, which at least in part flows into the small intestine where it may play a disinfecting or detoxicating rôle.

SUMMARY

1. Description of an apparatus by which sham feeding can be carried out and gastric juice collected under conditions which give positive evidence of the amount secreted.

2. There is no appetite or psychic secretion of gastric juice in the young infant. This disproves the present view, which is based on insufficient experimental evidence.

3. The empty stomach of the hungry babe secretes a gastric juice which often is as acid as that found in the adult's stomach.

4. The more profuse this secretion, the higher is its acidity. It contains pepsin.

5. This secretion is not neutralized in the stomach, but flows out into the small intestine. Regurgitation through the infant's pylorus does not occur.

6. The theoretical objections to tube feeding in prematures because of the lack of stimulation of an appetite gastric juice are not valid. However, a disadvantage may lie in this: that such feeding precludes the usual admixture of the milk with saliva.

Therapeutic starvation in acute alimentary disorders and in summer diarrheas may owe its success in part to the heightened tonus of the alimentary tract, and in part to the pouring out of highly acid detoxicating and disinfecting gastric juice into the small intestine.

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